DACA42-02-C-0001

LOGANEnergy Corp.

Environmental Center PEM Demonstration Program
Fort Bragg Army Base
Fayetteville, North Carolina
Final Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY01

Fort Bragg Army Base
Fayetteville, North Carolina

September 17, 2004

Executive Summary

In October 2001, LOGANEnergy Corporation received a contract award from the US Army Corps of Engineers, Construction Engineering Research Lab to test and evaluate Proton Exchange Membrane (PEM) Fuel Cells at several DOD sites. Fort Bragg Army Base in Fayetteville, NC was one of the sites awarded to LOGAN. The initial start-up of the PEM fuel cell took place September 30, 2002.

The demonstration site is located at the Ft Bragg Environmental Center. It is host to a 5 kilowatt 120/240 VAC, SU-1R PEM technology demonstration unit manufactured by Plug Power Corporation, Latham, NY. The unit, which is a factory-remanufactured product, is installed in a grid parallel/grid synchronized configuration and operates nominally at 2.5 kilowatts. The unit is instrumented with an external wattmeter and a gas flow meter. A phone line is connected to a data modem within the power plant to communicate to Plug Power with alarms or events requiring service and attention.

The Point of Contact for this project is Mr. Georges Dib. His phone number is (910) 396-7736.
The total estimated energy cost increase to the host site as a result in participating in this demonstration project is $729.73.

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Environmental Center PEM Demonstration Program, Fort Bragg Army Base, Fayetteville, North Carolina

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation
1080 Holcomb Bridge Road
BLDG 100- 175
Roswell, GA 30076

(770) 650- 6388

Data Universal Numbering System (DUNS) Number: 01-562-6211
Commercial and Government Entity (CAGE) Code: 09QC3
Taxpayer Identification Number (TIN): 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. This facility, which opened in February 2000, is comprised of 50,000 square feet of dedicated production and production test facilities. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually.

Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is scott_wilshire@plugpower.com.

4.0 Principal Investigator(s)

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6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company
Ms. Stephanie Chapman
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.

In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability. LOGAN performs the quarterly and annual service prescribed by the UTC, and performs other maintenance as required. The periods of unavailability are chiefly due to persistent inverter problems that seem to be endemic to the Toshiba power conditioning balance of the system. Field modifications and operating adjustments have largely cured the problem. Quarterly service events take 10 hours to complete with the unit under load, and the annual event takes approximately 35 hours with the unit shut down.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.

Plug Power
Mr. Scott Wilshire.
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1338

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work. The units are located at residential sites at Patuxant River Naval Air Station, MD and operate in standard gird connected/grid independent configurations. Both operate at 4.5kWe and have maintained 98% availability. The units, S/Ns 241 and 242 are two of the very latest GenSys models to reach the field. S/N 242 is Plug Power's first LPG fueled system to go into the field. Both have set new performance standards, and raised expectations for near term commercial viability for this product. Operations to date are indicative of the success of the various test and evaluation programs that have been conducted over the past two years.

c) Contract: A Partners LLC; Commercial PC25 Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.
Contract # A Partners LLC, 12/31/01

Mr. Ron Allison
A Partners LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA. The system operating configurations allow for both grid parallel and grid independent energy service. The grid independent system is integrated with a Multi Unit Load Sharing (MULS) electronics package and static switch, which initial development was funded by ERDC CERL in 1999.

7.0 Host Facility Information

Fort Bragg is located in Fayetteville, North Carolina, and is an "open" Army installation, which allows easy access for civilians. It was established in 1918 as Camp Bragg, an Army field artillery site named for the Confederate General Braxton Bragg. A year later, an aviation landing field named after 1st Lt. Harley H. Pope was added. Five years later, it was renamed Fort Bragg and became a permanent Army post. With Pope Air Force Base it is one of the world's largest military installations.

With more than 45,000 military personnel, Fort Bragg is the world's largest airborne facility. It is well known as the "home of the airborne," and is home to the 82nd Airborne Division, the XVIII Airborne Corps, and the U.S. Army Parachute Team (the Golden Knights).

The electricity provider for Fort Bragg is Progress energy, formally known as Carolina Power and Light. The natural gas supplier is Piedmont natural Gas, and Ft Bragg produces all of its own water from a series of wells located on the base.

8.0 Fuel Cell Installation

The installation site, seen in Figure 1 below is adjacent to the Ft Bragg Environmental Center, and proved to be convenient to water, power and natural gas utility services. The facility houses offices and an environmental testing laboratory. In order to accommodate the Plug unit installation, a small tree similar to the tree on the left had to be removed.

The installation of the fuel cell began on August 14, 2002. The fuel cell was placed on the pad using a fork truck on August 23. All installation tasks were completed on September 19. Although the fuel cell was successfully started on September 30 a working phone line was not available until October 9, 2002.

Figure 1 – Before Installation

The ground was excavated approximately six inches to provide a sub base of granite crush. Twelve-inch pavers were laid over the crush to match the unit's footprint, and then framed with a 2" X 6" treated pine border. Access to the Environmental Building's mechanical room is through the red door in the left background. It houses electrical panels to make the fuel cell connection to the facility, and the water source for the PEM unit. No construction permits were required to install this site.

Figure 2 – PEM Fuel Cell SN SU01BO 000000002

This unit required greater effort to install and pass the acceptance test than anticipated. Because of this, the actual first cost was higher than the estimated first cost reported in the Initial Report. The chief cost differential is due to the extra time spent in technical services for troubleshooting and repairing the unit during the start-up process.

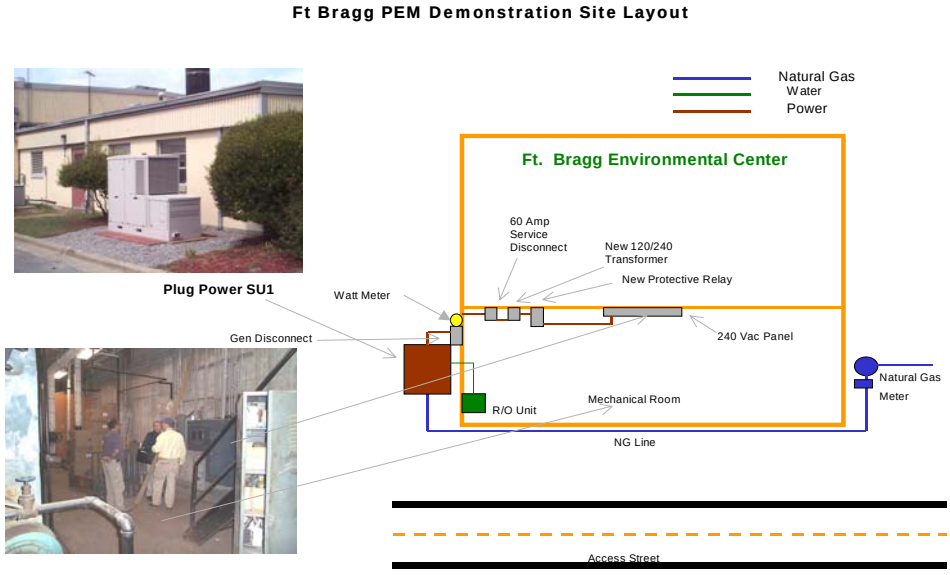

Figure 3

Figure 3, above, diagrams the location of the fuel cell pad in relationship to the utility interfaces including, power and water in the adjacent mechanical room, and natural gas on the opposite side of the building. The natural gas piping run is approximately 50 feet, the R/O water-piping

run is approximately 25 feet, and the electrical conduit run is approximately 25 feet. The unit is installed in a grid parallel / grid synchronized configuration and operates nominally at 2.5 kilowatts.

A Plug Power supplied Reverse Osmosis water filtration system was installed in the mechanical room to provide filtered process water to the power plant.

The installation tasks were completed on September 19, 2002, after spending 176.5 man-hours in the process. LOGAN attempted initial start of the Fort Bragg fuel cell on September 20, 2002, but was not successful due to electrical and mechanical problems that needed troubleshooting and correction. These included the failure of the therminol level sensor, rapid depletion of the batteries following unsuccessful start attempts and improper ATO set points in the controller software. The first successful start took place on September 30, 2002. The unit completed its 8-hour acceptance test on October 1, 2002.

9.0 Electrical System

The Plug Power SU-1 inverter has a power output of 120/240 VAC at 60 Hz. However, the distribution panel in the Environmental Center mechanical room has connected loads at 110/208 VAC. In order to accommodate the facility's electric service, LOGAN installed a 240/208 step-down transformer to match the requirements of the 110/208-load panel indicated in Figure 3. Also, a 60-amp service disconnect and a protective relay were installed as precautionary devices to prevent injury to service or utility personnel. While capable of operating at 5 kilowatts output, for the majority of hours during the demonstration the fuel cell output was manually set at 2.5 kilowatts.

There were no issues at the Environmental Center related to the parallel interconnect of the fuel cell to the existing Fort Bragg electrical system.

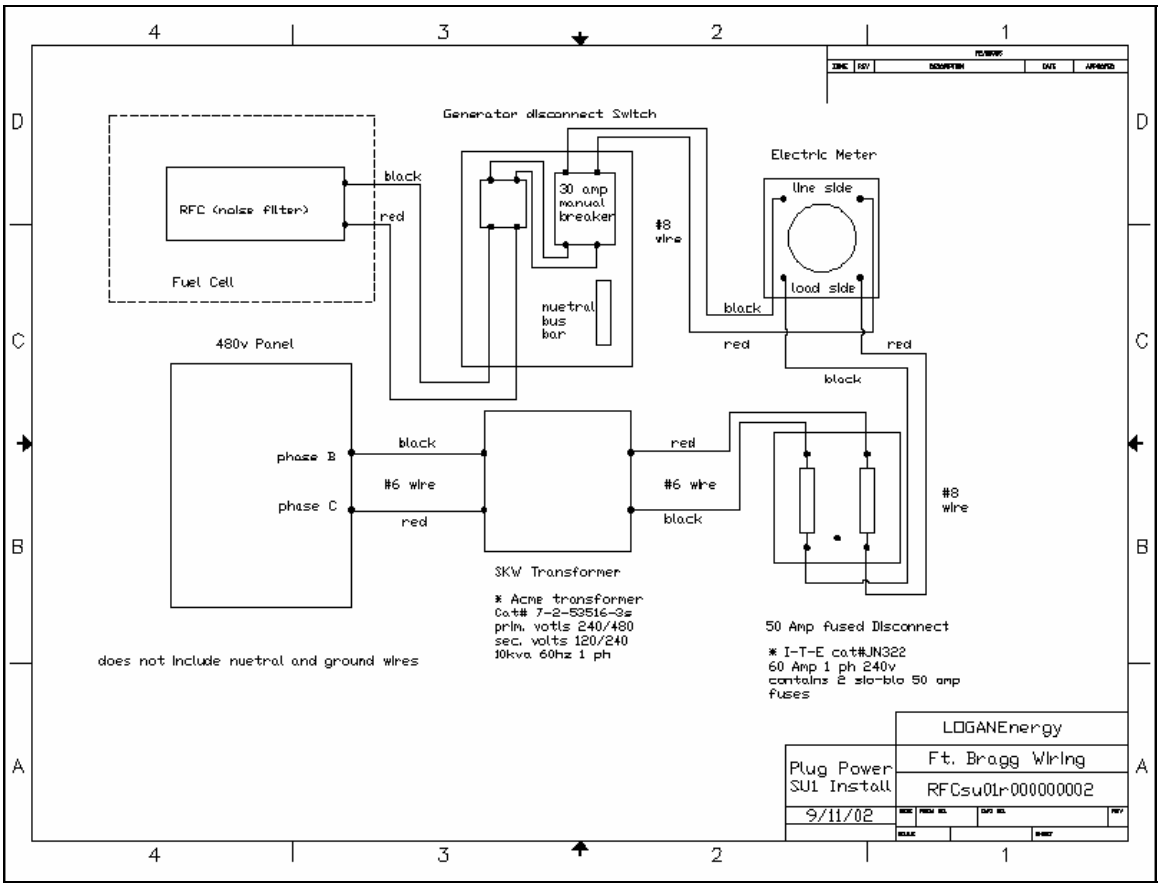

Figure 4 – Electricity flows from the fuel cell to the generator disconnect switch, through the meter to a 50 amp disconnect, to a transformer and from there to the existing building distribution panel.

10.0 Thermal Recovery

Not Applicable – This fuel cell was not configured for Thermal Recovery.

11.0 Data Acquisition System

During the period October 2002 to August 2003, LOGAN's field service technicians performed their tasks with the support of a very rudimentary SCADA system developed by Plug Power for communicating with deployed units. This system provided one-way communication from each unit to Plug's customer support center, allowing the unit to call in overnight to download a data package and an operating status report. However, LOGAN realized very quickly that the system was inadequate and unreliable to provide the high level of communications support needed for its wide-ranging PEM demonstration program. At times a unit called in and provided only partial data or incorrect data. This created uncertainty in troubleshooting and further delay in restoring units to service. On other occasions a unit might fail to call in for a week or more frustrating the normal chain of events leading to a service advisory. While much can be said about the early learning curve experience in developing service norms, the weakness of the SCADA system became a major source of dissatisfaction with Plug Power. Under the circumstances the only means of determining a unit's actual status was to make a service call to the site. However, the scope of LOGAN's PEM program required a better solution. Finally, in March 2003 an event occurred that gave Plug direct insight into the shortcomings of its SCADA system. After advising of a shutdown at Ft Bragg, Plug sent its own technician to the site because LOGAN's technicians were servicing other units. The technician

flew from Albany, NY to Raleigh, NC and then drove out to the site. Upon arriving, the technician discovered that the unit was operating normally. Indeed the SCADA system was not.

This event was an important turning point for the LOGAN/Plug Power relationship and its cooperative efforts in achieving the goals of the PEM Demonstration Program. Six weeks later, in early June, six representatives from LOGAN and eight from Plug Power met in Atlanta for two days of forthright discussions. The meeting focused on short-term methods and longer term solutions to improve remote PEM fuel cell performance. Most significantly Plug determined that it would institute immediate software changes and upgrades to insure the accuracy of fuel cell data communications. Plug also promised to initiate a design change to its SCADA system that would permit bi-directional remote communications with the fuel cell controller. More importantly Plug promised that LOGAN's technicians would be able to remotely troubleshoot, change set points and attempt restarts under some circumstances. Lastly they also promised that they would publish a daily status report covering all of LOGAN's units. By early August Plug began sending daily status reports, and by mid September Plug shipped LOGAN's technician's new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities. Since the introduction of this new service capability along with the adoption of improved service techniques to go with it, fleet performance, availability and operating costs have begun to show positive new trends.

In addition to the internal SCADA system, an external four-channel data-logger was installed on the PEM fuel cell. This data logger is capable of recording kW output, outside air temperature, Btu output and natural gas usage.

12.0 Fuel Supply System

Figure 5

The Plug Power fuel cell system is fueled by natural gas. This natural gas meter (left) on the opposite side of the Environmental Center provides gas service as depicted in Figure 3. A regulator was installed at the fuel cell gas inlet to maintain the correct fuel inlet operating pressure of 10" water column.

The Plug Power PEM fuel cell natural gas requirements are:

- Must be >90% methane
- No greater than 15 ppm sulfur on a yearly average basis
- Supply Pressure: 4" to 11" water column
- Maximum flow rate: 105,000 btu/hr
- Nominal flow rate: 72,700 btu/hr

13.0 Program Costs

The actual cost to install the fuel cell was $8,954 higher than the original first cost estimate. This amount is almost entirely accounted for in the added labor costs needed to troubleshoot the fuel cell during the initial start-up. Anticipating a much smoother start-up, the original estimate did not adequately account for this additional labor. The cause of this additional troubleshooting labor costs can once again be attributed to the "remanufactured or reconditioned" status of this power plant. Installation and start-up for "new" PEM fuel cells should be closer to the estimated costs.

Ft Bragg PEM Fuel Cell Economic Analysis

Utility Rates	
1) Water (per 1,000 gallons)	$1.69
2) Electricity (per KWH)	$0.0651
3) Natural gas (per MCF)	$5.80

Estimated First Cost		Actual
Plug Power 5 kW SU-1	*$42,500*	*$42,500*
Shipping	*$1,000*	*$900*
Installation electrical	*$4,200*	*$3,835*
Installation mechanical	*$2,400*	*$2,100*
Watt Meter	*$800*	*$947*
Site Prep, labor materials	*$925*	*$720*
Technical Supervision	*$6,500*	*$15,885*
Training	*$5,000*	*$5,392*
Total	***$63,325***	***$72,279***
Assume Five Year Simple Payback		**$12,665**

Forecast Operating Expenses	**Volume**	**$/Hr**	**$/ Yr**
Natural Gas			
Mcf/hr @ 2.5kW	*0.032838*	*$0.19*	*$1,502*
Water			
Gals/Yr	*4918*		*$8.31*

Add Total Annual Operating Costs	**$1,510**
Total Annual Costs (Amortization + Expenses)	**$14,175**

Economic Summary		
Forecast Annual kWH	*19710*	
Annual Cost of Operating Power Plant	*$0.0766*	kWH
Credit Annual Thermal Recovery	*0*	
Project Net Operating Cost	*$0.0766*	kWH
Amount Available for Financing	*($0.0115)*	kWH
Add 5 Yr Amortization Cost / kWH	*$0.6426*	kWH

Current Demo Program Cost Assuming 5 Yr Simple Payback	**$0.7192**	**kWH**

***NOTE**Does not include allowance for cell stack life cycle costs or service over 5 year economic scenario*

In the economic summary above the "Forecast Annual kWH" is based on an average fuel cell output setting of 2.5 kW's and 90% availability. Based on these assumptions the value of energy produced by the fuel cell will be $0.0766 per kWH. The amount available for financing expressed as a credit to the project is ($0.0115/kWh) the difference between the utility kWh rate ($0.0772) and the fuel cell all-in operating cost per kWh ($0.0766), indicating that there is a very small cash flow from the project to finance the installation costs.

A likely investment scenario for installing a fuel cell would require a five-year payback. The bottom line cost of the project to project a simple 5 year pay back is the sum of the annual capital cost recovery rate of $0.6426/kWh (this value is derived by dividing the installation cost by 5 payback years and then dividing that quotient by the annual fuel cell kWh) plus the all-in annual operating cost of $0.0766/kWh = $0.7192kWh. This says that the unit would have to operate in a utility environment where power cost = $0.7192/kWh in order to achieve a five year payback given the installation costs and operating costs encountered at this site.

14.0 Milestones/Improvements

The PEM fuel cell demonstration at Fort Bragg has resulted in a number of product/process improvements. The most noteworthy of which are:

- Improved communication between the customer support engineers at Plug Power and the LOGANEnergy technicians in the field.
- Increased knowledge of troubleshooting techniques and procedures on the part of both Plug Power support engineers and LOGAN technicians.
- The creation by Plug Power of a daily status report by email giving the condition of all fuel cells in the field.
- The distribution by Plug Power to the LOGAN technicians new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities.

15.0 Decommissioning/Removal/Site Restoration

The Plug Power factory warranty period for this fuel cell ended on November 20, 2003. On January 20, 2004 the fuel cell tripped on a bad ATO blower. This was the last shut down for this fuel cell. The fuel cell was restarted on February 20, 2004 for one day in order to take harmonics readings and then was shut down permanently.

On June 21, 2004 all piping, conduit and wiring were disconnected from the fuel cell and all fuel cell related material and ancillary equipment were removed from the site. The fuel cell was subsequently shipped back to Plug Power. A park bench was purchased and placed on the pad previously used for the fuel cell.

16.0 Additional Research/Analysis

On February 19, 2004 a Harmonic Meter was used to measure the harmonics of the existing electrical system at the Environmental Center both with the fuel cell connected and with the fuel cell disconnected. The measurements show that the fuel cell did not contribute additional harmonics to the building system. See Appendix 3. (Harmonic readings are proprietary).

17.0 Conclusions/Summary

Despite significant service and support effort this unit has not been able to achieve 90% availability. It has experienced chronic mechanical and electrical problems since the initial start-up. The "out of the box" performance was unsatisfactory in every electrical and mechanical respect. This is largely due to its background as a factory remanufactured unit with previous field service. Plug Power supplied a reconditioned unit for this site because the funding approved for this site was originally intended to purchase an Avista model. However, the Avista product failed to meet the specifications required for the FY '01 CERL BAA, and the project funding level could not allow the purchase of a new Plug power fuel cell.

From the outset the Ft Bragg unit has performed below expectations and failed the Program goal of 90% operational availability. LOGAN believes that the reconditioned unit provided for this site was ill suited for the task. The site work logs attached below as Appendix 3 chronicle 12 months of maximum effort in pursuit of this goal. Close scrutiny of the logs raises the notion that the chronic electrical and mechanical deficiencies uncovered in the unit are systemic and need correction at the factory level.

This project has exposed LOGAN to major field service tasks and overhauls, including rebuilding reformers, replacing cell stacks and rebuilding inverters; even to inventing new field modifications and service procedures to impress performance, while continuous troubleshooting episodes have covered every possible system deficiency. The learning curve experience that is occurring at this site normally requires years of field service exposure, and would not be a part of this discussion were this unit operating at 90%. It is clear to LOGAN that what must be judged as this project's shortcomings in the strictest sense, the same is actually edifying to the broader Program objectives.

Appendix

1) Excel Spreadsheet with Monthly Operational Data
2) Work Logs (Proprietary Information)
3) Harmonic Test Results (Proprietary Information)

Appendix 1 – Monthly Performance Data

Appendix 2 – Work Logs – Proprietary Information

Appendix 3 – Results of Harmonics Testing – Proprietary Information